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(71) Applicant *(for all designated States except US)*: INNOTECH, INC. [US/US]; 5568 Airport Road, N.W., Roanoke, VA 24012-1311 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: KOKONASKI, William [US/US]; 6173 Burnham Road, S.W., Roanoke, VA 24018 (US). VACCA, Steven, M. [US/US]; 110 Roseland Drive, Christiansburg, VA 24073 (US). YOUNG, Donald [US/US]; 94 Ledgerbrook Drive, Norwalk, CT 06854 (US).

(74) Agents: GIANNESCHI, Lois, A. et al.; Johnson & Johnson, One Johnson & Johnson Plaza, New Brunswick, NJ 08933-7003 (US).

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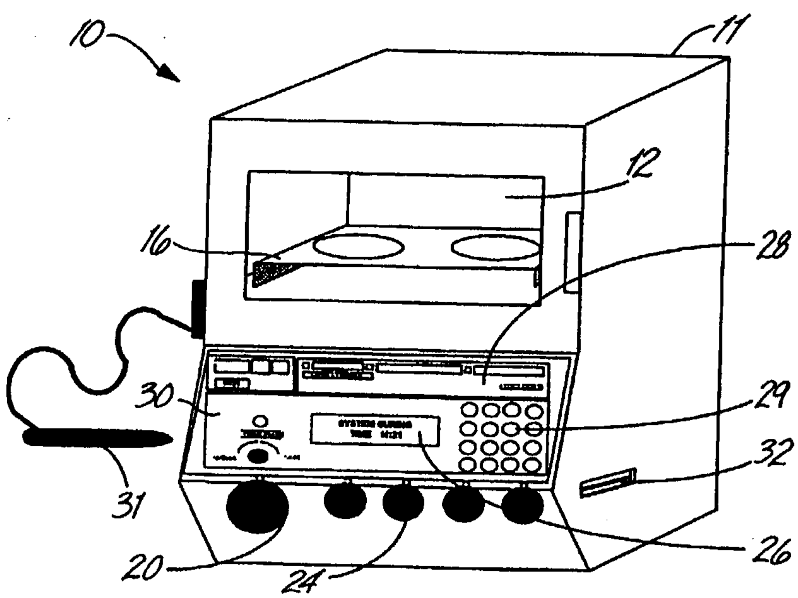

(57) Abstract

A lens making system for producing ophthalmic lenses using a combination of heat and light to polymerize a liquid resin has a personal computer-based architecture. Electronic ballasts modulate the light from a light source in the system. All of the cooling necessary for the system is provided by a cooling fan of the power supply of the system. A bar code-reading pen checks compatibility between materials and resin and ensures that appropriate cure cycles are activated, and a modem allows for remote accessing of the system to facilitate automatic reordering and inventory control of the system.

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POLYMERIC PROCESSING SYSTEM FOR PRODUCING OPHTHALMIC LENSES

BACKGROUND OF THE INVENTION

Methods and systems for making an ophthalmic lens by curing a thin layer of resin on an optical preform, wafer, or single focus lens are well known, as discussed in U.S. Patent No 5,219,497. The methods for selecting the location of the additional optic and the curing lens materials are discussed in U.S. Patent 5,178,800. Additionally, the use of a combination of heat and light to polymerize a monomer resin layer onto a single vision lens is known, as discussed in U.S. Patent Nos. 5,470,892 and 5,147,585. All of these patents are incorporated herein by this reference.

In concert with a controlled thermal profile, the lens making systems control the duration and time of light provided from the curing lamps to produce an ophthalmic lens. Typically, the light is modulated with mechanical shutters to control the amount of radiation exposure. Mechanical shutters, however, do not necessarily permit as fine a control over the modulation of the light as desired. Additionally, the mechanical parts comprising the shutters are susceptible to breaking and thus may present a reliability problem with respect to the lens making system. Additionally, some lens making systems use liquid crystal spatial light modulators (LCSLMs), which tend to heat up during operation of the system due to their inherently limited transmission in the clear state.

Additionally, known lens making systems are relatively inefficient in managing thermal energy. As a result, lens casting systems typically require excessive cooling with multiple fans and/or circulating pumps.

Another problem faced by practicing optometrists and lens manufacturers using known lens making systems is the maintenance of substantial inventories of single focus lenses and other optical preforms. Additionally, there is always a concern regarding potential mistakes made in selecting from multiple types of lens materials, resins, and associated cure cycles for the systems.

Consequently, a need exists for an improved ophthalmic lens making system.

SUMMARY OF THE INVENTION

The present invention, therefore, provides an improved ophthalmic lens making system designed to minimize the disadvantages associated with the prior art. The system includes a unique combination of components for achieving fast, efficient ophthalmic lens production using a combination of heat and ultraviolet and/or visible light to cure a layer of resin on a single focus lens. In particular, the present invention provides a lens making system capable of in-office processing that produces a high quality ophthalmic lens with very short cure times, typically between 15 and 40 minutes, depending on the optical resin composition. This system is particularly well suited for making bifocal and multifocal ophthalmic lenses, but can also be used to cure a uniform layer of resin on a single focus lens.

The system is controlled by a microprocessor, permitting the development of a lens making system having a personal computer- based architecture. The use of a personal computer-based system facilitates the implementation of two important features of the present invention. An optical scanner or bar code-scanning wand or pen is provided for automatically reading in information on the resin tube and on the single vision lens envelope, permitting the system to keep track of all the prescriptions processed on the system. Scanning in this information also allows the microprocessor to check compatibility between the materials and the resin and to ensure that the appropriate cure cycles are activated.

Additionally, the system is provided with a modem to allow remote accessing of the information stored in the system. The presence of a modem in the system greatly facilitates automatic reordering and subsequent stocking of the lens making material.

The system provides a high degree of consistent thermal and ultraviolet and/or visible radiation that produces very repeatable curing results. These results are improved by maximizing the light source efficiency of the system by separating the lamps from the curing chamber and by providing an air flow design that keeps the lamps cools. Specifically, the

cooling fan of the power supply for the system is utilized to provide substantially all the necessary cooling for the system. This eliminates the need to include additional cooling fans or circulating pumps, and has the added benefit of providing a much quieter system.

The system also provides a mechanism for temporally modulating the light from the curing lamps by controlling the power supplied to a set of electronic ballasts used to control the curing lamps. The use of electronic ballasts to modulate the light sources overcomes the problems associated with the modulating means used in the prior art, such as mechanical shutters and LCSLMs.

The system also provides a unique and highly efficient method of managing thermal energy with very low power requirements. As part of the thermal management system, a divider plenum is provided in the curing chamber of the apparatus and separates hot air entering from the heating element from return air flowing out of the curing chamber. The divider plenum may be positioned within the curing chamber to adjust the temperature balance within the chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will be appreciated as the same become better understood with reference to the following Detailed Description when considered in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic perspective view of a lens making system according to the present invention;

FIG. 2 is an electronic block diagram of the electronic system for the lens making system of FIG. 1;

FIG. 3 is a schematic front view of the thermal and optical systems of the lens making system of FIG. 1;

FIG. 4 is a side cross-sectional view of a curing chamber of the lens making system of FIG. 1;

FIG. 5 is a front cross-sectional view of the curing chamber of the lens making system of FIG. 1;

FIG. 6 is a back cross-sectional view of the lens making system of FIG. 1;

FIG. 7 is a plot of selected thermal characteristics of the lens making system of FIG. 1, including oven temperature, mold temperatures, and lamp temperatures, along with a lamp duty cycle for a representative cure cycle; and

FIG. 8 is a schematic illustration of the automatic inventory and processing parameter features of the lens making system of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the figures, a presently preferred embodiment of the lens making system is illustrated in FIG. 1. The system 10 has a computer-based architecture and includes a curing chamber for producing ophthalmic lenses, especially bifocal and multifocal lenses, using a combination of heat and actinic radiation, specifically ultraviolet and/or visible light, to cure a layer of resin on a single focus lens. The curing chamber includes an insulated oven 12 and ultraviolet and/or visible light sources 14 (FIG. 3) positioned above and below the oven 12. The light sources 14 provide ultraviolet and/or visible light to the interior of the oven, where a mold tray 16 is located. As will be described in more detail below, electronic ballasts 18 are provided to control the light applied by the lighting sources to the curing chamber.

Molds containing the resin that is to be cured onto a single vision lens are located on the mold tray 16. A dispenser assembly 20 allows for resin to be automatically dispensed into the molds of the mold tray. In a presently preferred embodiment, the dispenser assembly 20 includes a stepper motor 22 (FIG. 2) and a plunger that discharges resin from a disposable syringe within the system. The stepper motor 22 is preferably capable of carefully dispensing resin to the nearest 0.01 milliliter. Additional dispensing assemblies 24 may be added to increase the dispensing capabilities of the system.

These components are contained within an outer shell 11 of the system 10, which is preferably constructed from cold rolled steel, but can also be made from other suitable materials, such as aluminum or plastic.

A back-lit liquid crystal display 26 indicates the system status, and allows the system to prompt a user for information. Other system information, such as lamp hours, cure status, and oven conditions are displayed on light emitting diodes 28 (LED's) along the front of the status indicating panel 30 of the system. A keypad 29 on the front of the system permits a system operator to select various options and enter data.

An optical sensor or bar code-scanning wand 31 facilitates the automatic entry of pertinent information into the system, such as resin and lens material data, that is relevant to the processing parameters of the lenses. Additionally, a modem 33 (FIG. 2) within the system facilitates automatic reordering and subsequent stocking of materials used in the ophthalmic lens making process, such as single vision lenses, wafers, and resins. The system 10 also includes a floppy disk drive 32 for installing and upgrading system software.

Turning now to FIG. 2, a preferred embodiment of the electronic control system is illustrated. The heart of the electronic system of the present invention is a motherboard 34, preferably equipped with Intel 386, 486, or 586 microprocessors. The use of the motherboard 32 permits the lens making system to have a personal computer-based (PC-based) architecture, which has several distinct advantages over other noncomputer-based lens making systems currently available. For example, a PC-based architecture provides the ability to develop and maintain software for the system in a high level language, such as C or C++. Another advantage of a PC-based architecture is the availability of additional and supplemental hardware designed for the personal computer. By utilizing modular "plug and play" technology available for the personal computer, new and important features may be added to the lens making system with minimal investment in development time and associated expense, such as the bar code-scanning wand 31 and the modem 33, which communicates with the motherboard 34.

An interface board 36 provides a communication link between the motherboard 34 and

the rest of the system through a standard AT bus. The primary purpose of the interface board 36 is to provide the necessary logic link between the AT bus and the components of the system. The interface board 36 provides the digital logic to a set of switching electronics 38 where all logic levels used for power switching are optically isolated from the rest of the digital electronics. For example, optically isolated drives 40, 42 are used to turn power transistors, such as metal oxide semiconductor field-effect transistors (MOSFETs), on and off to connect or remove 12 VDC power to the electronic ballasts 18.

A heating element 44 for the oven 12 is powered by 115 VAC or 240 VAC, and is also controlled via optically isolated switching of a TRIAC with built in zero crossing detection. The zero crossing detection prevents unwanted noise during AC switching. The zero crossing detection also facilitates pulse width modulated control of the heating element 44 to provide consistent and efficient heating of the system.

A DC motor 46 is used to rotate an oven fan 48 that circulates the heat within the curing chamber. The logic levels used to control this motor are also optically isolated and controlled via high power MOSFETs. Additionally, a thermal sensor 50 located within the curing chamber provides temperature information directly to the interface board 36.

A multi I/O board 52 is used to provide communication between the motherboard 34 and a hard drive 54 of the system's computer. The hard drive 54 is used to store the system software and the system operator's material usage history. The multi I/O board 52 also provides communication to the floppy disk drive 32, such as a 3.5 inch disk drive, which is used to install and upgrade the system software. Additionally, the multi I/O board 52 provides a communication port to the bar code-scanning wand 31, which is used to enter information about the lens and resin directly into the system via bar codes on the resin tubes and lens envelopes.

An optical sensor 56 is used to limit the motion of the stepper motor 22 of the dispensing assembly 20. The dispensing assembly 20 is activated by pushing a fill switch 58, which is connected directly to the interface board 36.

Additionally, the keypad 29 allows the system operator to input commands directly to the interface board 36, which passes the commands to the motherboard 34. The backlit LCD display 26, which provides system status information, is also connected to the interface board, which passes information to the LCD display from the motherboard.

The power supply 55 for the system is a standard PC power supply that has enough capacity to operate the PC components, such as the motherboard, the hard and floppy drives, as well as the electronic ballasts. This allows for a much simpler system design that requires only a single power supply. Moreover, as discussed below, the cooling system has a simple, yet elegant design in which the cooling fan 57 of the power supply provides substantially all of the necessary cooling for the lamps and various electronic components in the system, including the electronic ballasts.

FIG. 3 illustrates a presently preferred embodiment of the optical and thermal systems of the present invention. A highly controlled combination of heat and ultraviolet and/or visible light is used to polymerize a liquid resin on a single focal lens placed in the curing chamber. Preferably, the light sources 14 are separated and thermally insulated from the heat source of the system. As can be seen from FIGS 3-6, the light sources 14 are located above and below the curing oven 12. Placement of the light sources outside the heated oven maximizes the lamps efficacy by allowing the lamps to remain at a much lower temperature than the oven. For example, although the oven may be as hot as 220 degrees Fahrenheit, the lamps remain somewhere between 80 and 120 degrees Fahrenheit. Maintaining the lamps at lower temperatures is important for long lamp life and good lamp efficacy.

The light sources 14 are preferably either ultraviolet and/or visible fluorescent tube lamps, such as Phillips PLS-9W/08, PLS-9W/10, or PLS-9W/27, with a maximum illumination between 300 and 400 nanometers. Although the lamps will operate at different line frequencies(50 or 60 Hz), operation at the higher frequency provides better lamp efficacy.

Electronic ballasts 18 are provided to modulate the ultraviolet and/or visible light from the light sources 14. The use of electronic ballasts provides a clean method for modulating the

lights. By switching the DC power supplied to the electronic ballasts, the lamps are easily turned on and off to meter the amount of ultraviolet and/or visible light that is applied to the resin. This is preferred over the use of liquid crystal spatial light modulators and mechanical shutters for the reasons already stated. As described above, MOSFETs are preferably provided to connect or remove 12 VDC power to the electronic ballasts 18. The electronic ballasts also provide consistent AC power to the lamps, regardless of variations in line voltage or frequency. In a presently preferred embodiment, the electronic ballasts are Bodine 12TPL7-9E or equivalent, and produce 20 to 30 kHz of AC power from a 12 VDC source. As mentioned above, the electronic ballasts are preferably powered by the 12 V rail of the PC power supply.

The oven 12 is constructed from a durable material, such as stainless steel or aluminum, and is thermally insulated with a suitable material, such as fiberglass or high temperature foam rubber. Since the light sources 14 are placed outside of the curing oven, optical ports 60 are constructed in the oven 12 to allow the transmission of light into the curing chamber. In the embodiment illustrated in FIGS. 3-6, two optical ports 60 are provided in each of an upper and lower surface 62, 64, respectively, of the curing oven 12 to permit light to reach the molds in the curing oven. The optical ports 60 are preferably constructed from high temperature glass with an optical transparency of at least 90% at 360 to 600 nanometers. To secure the optical ports in position, metal rings constructed from stainless steel or anodized cold rolled steel and high temperature foam rubber gaskets are used.

The optical ports 60 are preferably surrounded by collimating reflectors 66 to ensure that the light entering the oven 12 is uniform. Uniform light intensity is critical for uniform curing of the resins used to form the additional optic on the single focus lenses.

Referring now to FIGS. 4-6, additional details of the curing chamber are illustrated. FIG. 4 is a side cross-sectional view of the curing oven 12, which is covered with a layer of fiberglass or foam insulation 68. Optical ports 60 allow the ultraviolet or visible light to enter the curing oven from above and below. The mold tray 16 is positioned within the curing oven 12, and includes a pair of molds 70 held in place by a metal tray 72. The molds 70 can be either glass

or plastic, and are preferably ground from crown glass or molded from transparent plastics, such as polycarbonate, polypropylene or a polyethylene polypropylene copolymer.

During operation of the curing oven 12, liquid resin and a pair of plastic, single vision lenses are placed in the molds 70. The oven is heated by blowing air with the squirrel cage fan 48 across the resistive heating element 44. The fan 48 is driven by the DC motor 46, and is designed to pull air in towards the motor along its axis of rotation, and to blow air outward in all directions. A specially designed dividing plenum 74 located between the heating element and the molds facilitates even circulation of the heated air throughout the oven.

Turning now to FIG. 5, a front cross-sectional view of the curing oven 12 is illustrated. In this view, the divider plenum 74 is shown to be shorter than the width of the oven 12, by about 45%. This allows the hot air being blown across the heating element 44 to enter the oven 12 evenly across the top 75 of the oven and the return air from the bottom of the oven to be drawn out evenly from the lower left 77 and right 79 hand sides of the oven. It should be noted that the position of the divider plenum 72 can be moved to the left or the right relative to the oven to adjust the temperature balance within the oven.

Additionally, the thermal sensor 50 is located in an upper 81 right hand corner of the oven 12 . The location of the thermal sensor 50 is important to achieving an accurate and representative measurement of the oven temperature. In general, the placement shown in FIG. 5 is consistent with counterclockwise rotation of the oven fan 48, since this allows for a measurement point with the most laminar air flow.

Additional features of the cooling system are illustrated in FIG. 6, which is a back cross-sectional view of the entire system. A plurality of louvers 80 are placed on the side walls of the system to allow cool air into the system. The louvers 80 are partially covered with a set of duct work 82 that directs air flow over the lamps while preventing unwanted light leakage through the louvers. Cool air is drawn through the ducts and forced across the lower half of the system by the cooling fan 57 on the system power supply 55. By controlling the air movement in this manner, the coolest air is pulled across the lamps 14, removing the heat generated by the lamps

and keeping the lamps operating at a very high efficacy. The remaining air flows across the system electronics, which are arranged on a chassis 84 mounted to the inside lower left hand side 85 of the system 10. The chassis 84 provides easy access to the serial port of the multi I/O board 52 used to connect the bar code-scanning wand 31 to the system. Additionally, the modem 33 is also readily accessible through the back of the chassis 84.

The cooling system works in conjunction with the optical and thermal systems to provide proper curing of the resins. It should be noted that proper curing of the resins is also affected by the thermal control of the oven. In a presently preferred embodiment, oven temperature is carefully controlled by a Proportional, Integral, Derivative (PID) control algorithm. The PID control algorithm is described in Appendix A, attached hereto, which is incorporated herein by this reference. This algorithm is used to determine the correct duty cycle for pulse width modulation control of the electrical power applied to the heating element. In this manner, the temperature set point can be reached with minimal overshoot. Pulse width modulated control of the heating power also allows the maximum duty cycle to be adjusted to the different AC voltage levels used throughout the world. Preferably, a heating element that provides 350 watts of power at 120 VAC at a maximum duty cycle of 100% is employed in the system. Because power is proportional to the square of the voltage, the same heater provides 350 watts of power at 240 VAC, with a maximum duty cycle of 25%. In this manner, the same heating element can be used for 120 VAC or 240 VAC and still provides all the thermal energy required to cure the resin. As a result, the lens making system provided herein can be used throughout the world.

In general, the thermal control of the curing oven needs to be within certain limits to achieve consistent and repeatable curing results. In a presently preferred embodiment, the system has the following thermal control characteristics: (1) the actual air temperature in the oven is controlled to within +/- 5 degrees Fahrenheit of the set point temperature throughout the cure cycle; (2) the variation in left to right mold temperatures is never more than 7.5 degrees

Fahrenheit; (3) the temperature ramp rate is preferably controlled to be no more than 15 degrees Fahrenheit/minute; and (4) the temperature in the oven should not exceed 220 degrees Fahrenheit.

Similarly, the lamp intensity needs to be within certain limits to achieve consistent and repeatable curing results. In a presently preferred embodiment, the lamp intensity is between 2000 and 3000 millijoules per square centimeter at a nominal wavelength of 390 nanometers. Through repeated experiments with a variety of materials and lens styles, it has been determined that this level of thermal and optical control, and these limits, are required to maintain consistent results in the final product. Properties such as scratch resistance, adhesion, and optical and cosmetic quality may be otherwise adversely affected.

FIG. 7 is an illustrative example of a representative cure profile for a pair of ophthalmic lenses produced by the present invention. The upper dashed line 87 represents the temperature set point that was programmed into the software of the system. This temperature profile is determined by a variety of factors, including the resin chemistry, the type of lens material and the type of lens design. The sold upper line 89 is the actual oven temperature, measured from the center of the oven with a J-type thermocouple. Additionally, the middle dashed line 91 represents the left mold 70a temperature and the middle solid line 93 represents the right mold 70b temperature.

As the lines indicate, the mold temperatures are very consistent from left to right, as a result of the carefully balanced air flow. The mold temperatures significantly lag the air temperature due to the large thermal masses of the glass or plastic molds. This is an important factor to consider in the development of thermal profiles for making lenses.

FIG. 7 also illustrates the lamp profile of the system during the curing process. During the first five minutes of the curing process, no lights are turned on, and the mold, lenses and resin are left in the dark and allowed to warm up slightly. The second five minutes of the cycle allows for a very gradual ramp in oven temperature, with simultaneous flashing or blinking of the actinic radiation sources from the top and bottom of the oven. After the first ten minutes, the

lamps are turned on continuously while the oven continues to ramp in temperature until the final dwell temperature is reached.

While the oven is heating, it is important to monitor other temperatures within the curing chamber, as they can indirectly affect the curing process. The lower solid line 95 in FIG. 7 represents the air temperature near the center of the upper lamps in the system. It is important to note that this solid line indicates that the temperature near the upper lamps 14a is slowly but steadily falling for the first ten minutes of the cure cycle, despite the fact that the oven is actually heating from approximately 115 degrees Fahrenheit to 130 degrees Fahrenheit during that same period. This suggests that there is very little heat transfer between the oven and the lamps. After the first ten minutes when the lamps are continuously on, it is clear that the air temperature near the lamps is slowly rising up to approximately 120 degrees Fahrenheit at the end of the cure cycle. This suggests that the major source of heat near the lamps is the lamps themselves.

The lower dashed line 97, near the bottom of the graph in FIG. 7, represents the air temperature near the center of the lower lamps 14b in the system. While following a similar trend as the upper lamps, the lower lamp temperature never exceeds 105 degrees Fahrenheit due to slightly better air circulation at this location.

The longer dashed line 99 near the bottom of FIG. 7 represents the air temperature near the digital electronics inside the system. Here the temperature stays relatively low, less than 110 degrees Fahrenheit throughout the entire cure cycle. As indicated in FIG. 7, very little thermal energy actually leaks from the curing oven 12 into the rest of the system.

Turning to FIG. 8, the use of the scanning wand 31 and modem 33 components of the system 10 will now be described in more detail. In conjunction with the PC-based architecture of the system, these components allow the present invention not only to track and reorder inventory automatically, but also to generate processing parameters for the ophthalmic lenses to be produced. For example, a resin tube 100 may include bar coded information 102 about the resin chemistry, the expiration date, the batch number, as well as a unique identification number. Similarly, bar coded information 104 on a single vision lens envelope 106 may include, for

example, information on the material type, lens distance, and astigmatic power, as well as a unique identification number. By scanning this information into the system with the bar code-scanning wand 31, the system operator can provide the system with the necessary information for complete record keeping on the materials used by the system, thereby allowing the tracking of all prescriptions processed on the system. Additionally, this information permits the system to check compatibility between materials and resin automatically and ensure that appropriate cure cycles are activated.

The encoded data is sent directly into the system via the serial port on the back of the system. A modem line 33 allows the system to be accessed remotely; thus all of the lens casting records can be downloaded to a central office location 110. Once the central office 110 reviews the casting log from a system location, the exact materials required for restoring the system operator's inventory can be shipped by ground or air transportation, depending on the system operator's requirements. This provides an important advantage to both the system operator and the material supplier. The system operator can maintain a smaller inventory of materials if he can rely on quick restocking from the manufacturer. Additionally, the material supplier can schedule production runs based on a running average of all system usage throughout its regional market. Moreover, remote access of the casting log will permit the material supplier to keep on-site inventory of materials current, without having to do an on-site physical audit at the system operator's location.

While various embodiments of this invention have been shown and described, it would be apparent to those skilled in the art that many more modifications are possible without departing from the inventive concept herein. It is, therefore, to be understood that, within the scope of the appended claims, this invention may be practiced otherwise than as specifically described.

APPENDIX A

INNOTECH LENS SYSTEM CHAMBER PID CONTROL ALGORITHM

Preface

In order to precisely control (regulate) the Oven temperature to desired temperatures (setpoints), an adjustable mathematical equation is implemented. This equation is called a Proportional, Integral, Derivative (PID) equation. The Derivative component is not used. The PID equation has a Proportional component (Pterm which is directly proportional to the error value between the Setpoint (desired) temperature and the Actual (measured) temperature, and an Integral component (Iterm which represents a history of the error value). There are 3 modes of Heat Regulation, the Warm-up mode, the Default mode, and the Curing mode. The Integral term is computed in 2 ways depending on the Heat Regulation mode.

The PID equation is:

PIDout = Pterm + Iterm

where, depending on the Heat Regulation mode,

Pterm = PconstWARM * Error

Iterm * IconstWARM * (Average of last 6 Errors)

or,

Pterm = PconstDEFAULT* Error

Iterm = IconstDEFAULT* (Average of last 6 Errors)

or,

Pterm = PconstCURE* Error

Iterm = ItermPREVIOUS + [Error * (2/IconstCURE)]

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The Oven Heat is turned ON once and OFF once during every 550ms time period. This 550ms time period is divided into 50 11ms increments. At the start of a given 550ms time period, the Oven heat is turned ON. Then based on the PID out value, the Oven Heat is turned OFF at 1 of these 50 possible 11ms increments and it remains OFF until the start of the next 550ms time period. The time that the Oven Heat is ON and the time that the Oven Heat is OFF during a 550ms time period is called the Duty Cycle. For example if the Oven Heat is turned ON for one half (25* 11ms = 275ms) of the 550ms time period, the Duty Cycle would be 50% for one fifth (IO*11ms - 110ms) it would be 20%. This ON and OFF Duty Cycle is repeated every 55Oms unless the Oven Heat is commanded to remain OFF.

The Pconst and Iconst values are modifiable in the Utilities Menu. They can be adjusted from 0 to 99. For Pconst, the higher the value the greater the corrective Proportional response to the error. For Iconst during the WARM-UP and DEFAULT modes, the higher the value the greater the corrective integral response based on the immediate history of the error. For Iconst, during the CURING mode, the lower the value the quicker the corrective responses will "zero-in" on the value necessary to produce zero error.

Compute the Proportional and Integral terms of the PID equation.

Pterm - PconstCURE * TEMPerr

Iterm = ItermPREVIOUS + [(TEMPerr *(1/IconstCURE)]

where ItermPREV1OUS is the calculated ______ from previous average measurement

Compute PID Output Value

Three time each second, the A/D Heat Sensor value is read and saved in a 3 element circular buffer and the average of these 3 latest readings is computed.

At the start of the next 550ms time period, the new measured temperature is computed based on the current average A/D Heat Sensor reading value. This measured temperature value is computed as follows:

Assume that:

A/D reading - 0 is equivalent to 70 °F

A/D reading - 255 is equivalent to 230 °F

So the total temperature span = 230 °F - 70 °F = 160 °F

TEMPmeas = 70 °F + x

where x = a value from 0 °F to 160 °F

This can be seen as the ratio:

$$\frac{X\ °F}{160\ °F} = \frac{y\ cnts}{255}$$ where y = the A/D reading value (0-255)

So TEMPmeas = 70 °F + x °F

= 70 °F + [y * (160°F/255)]

For WARM-UP OR DEFAULT mode:

Compute the Error and Average Error between the current Setpoint temperature and TEMPmeas.

TEMPerr = TEMPset - TEMPmease

ERRORbuff = ERRORbuff + TEMPerr

(ERRORbuff always contains the sum of the last 6 TEMPerr's).

ERRORavg = ERRORbuff/6

Compute the Proportional and Integral terms of the PID equation. The constants will be either DEFAULT or WARM depending on the Heat Regulation mode.

Pterm - PconstDEFAULT * TEMPerr

Item - IconstDEFAULT *ERRORavg

PIDout -Pterm + Iterm

For CURING mode:

TEMPerr = TEMPset - TEMPmeas

Compute Duty Cycle

The Duty Cycle is base on the PID output. When starting a 550ms period, OFFcnts = the number of 11ms increments (out of a possible 50) until the heat will be turned OFF.

Observe the following ratio:

$$\frac{\text{OFFcnts}}{50} = \frac{\text{PIDout}}{500}$$

and therefore,

Duty Cycle = OFFcnts/50 x 100%

The value 500 is the maximum PIDout value allowed. This means that a PIDout value greater than or equal to 500 is equivalent to 50 11ms increments or a 100% Duty Cycle.

The Duty Cycle is also attenuated (reduced) depending on the AC voltage level supplied to the Oven Heater. If the AC voltage - 120 VAC, then no attenuation of power (Duty Cycle), is necessary. But an AC voltage of 240 VAC (twice the voltage = 4 times the Wattage, a 4/1 ratio) requires a 4-to-1 attenuation of power (Duty Cycle) supplied to the Oven Heater.

So,

OFFcnts(attenuated) = [x * (100 - ATTENconst)]/100

and,

Duty Cycle = OFFcnts(attenuated)/50

In summary,

At the start of every 550ms period, the number of 11ms periods (out of 50) until the Oven Heat is to be turned off is calculated based on a PID output value (possibly attenuated). The Oven Heat is then turned ON (if at least 1 11ms period of ON time is calculated). When the calculated number of 11ms periods passes, the Oven Heat is turned OFF and it remains OFF until this cycle is repeated at the beginning of the next 550ms period.

WHAT IS CLAIMED IS

1. A personal computer-controlled lens making system for producing ophthalmic lenses, the system comprising:

a curing chamber; and

a microprocessor for controlling the lens making system, wherein the curing chamber and the microprocessor are integrally contained within a single unit.

2. The lens making system according to claim 1, further comprising an optical scanner operatively coupled to the microprocessor.

3. The lens making system according to claim 1, further comprising a modem operatively coupled to the microprocessor.

4. The lens making system according to claim 2, wherein the optical scanner comprises a bar code-scanning wand.

5. The lens making system according to claim 3, further comprising at least one light source located outside the curing chamber and thermally insulated from the curing chamber.

6. The lens making system according to claim 5, further comprising an electronic ballast for modulating the at least one light source.

7. The lens making system according to claim 6, further comprising a power supply having a cooling fan that provides substantially all necessary cooling to the system.

8. A lens making system for producing ophthalmic lenses, the system comprising:

at least one light source; and

at least one electronic ballast for modulating the at least one light source.

9. The lens making system according to claim 8, further comprising electronic means for controlling the at least one electronic ballast.

10. The lens making system according to claim 9, wherein the electronic means comprises a power transistor.

11. A lens making system for producing ophthalmic lenses, the system comprising:

a curing chamber;

a microprocessor for controlling the lens making system, wherein the curing chamber and the microprocessor are integrally contained within a single unit; and

a microprocessor power supply having a cooling fan,

wherein the power supply cooling fan provides substantially all necessary cooling to the system.

12. The lens making system according to claim 11, further comprising at least one light source disposed outside the curing chamber, and a plurality of louvers located at an end of the unit, opposite the cooling fan.

13. The lens making system according to claim 12, further comprising duct work corresponding to the plurality of louvers for directing cooling air over at least one light source

14. A lens making system for producing ophthalmic lenses, the system comprising:

a curing chamber having a top and a bottom;

a mold tray located in the curing chamber;

a heating element located behind the curing chamber, substantially adjacent the top of the curing chamber;

an oven fan located substantially directly below the heating element and adjacent the bottom of the curing chamber; and

a divider plenum for separating a stream of hot air from the heating element from a stream of return air to the oven fan, the plenum positioned in the curing chamber between the mold and the heating element.

15. The lens making system according to claim 14, wherein the curing chamber has a back wall having a width, and wherein the divider plenum has a width that is substantially less than the width of the back wall.

16. The lens making system according to claim 15, wherein the width of the divider plenum is about 55% of the width of the back wall of the curing chamber.

17. A personal computer-controlled lens making system for producing ophthalmic lenses, the system comprising:

a curing chamber;

means for providing heat to the curing chamber;

means for providing light to the curing chamber; and

microprocessor means integral within the system for controlling heat means and the light means,

wherein the lens making system has a personal computer-based architecture.

18. The lens making system according to claim 17, further comprising means for optically scanning in encoded information relevant to processing parameters of the ophthalmic lenses.

19. The lens making system according to claim 18, further comprising means for storing processing parameters of the ophthalmic lenses.

20. The lens making system according to claim 19, further comprising means for remotely accessing the lens making system.

Fig. 1

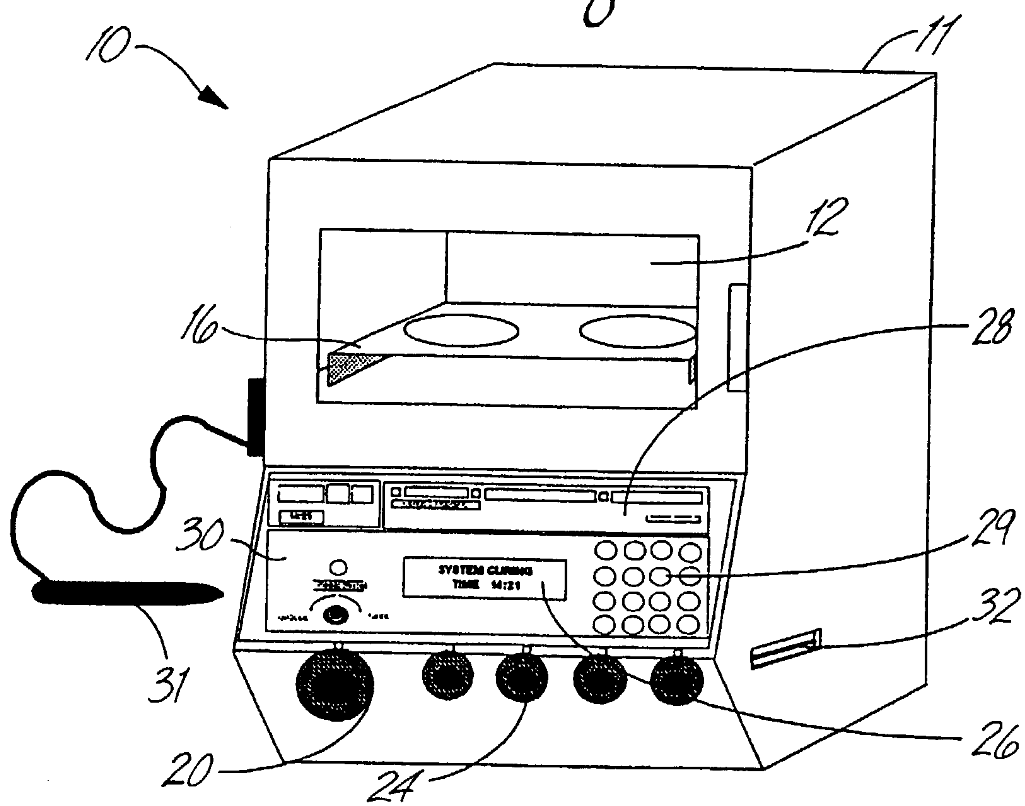
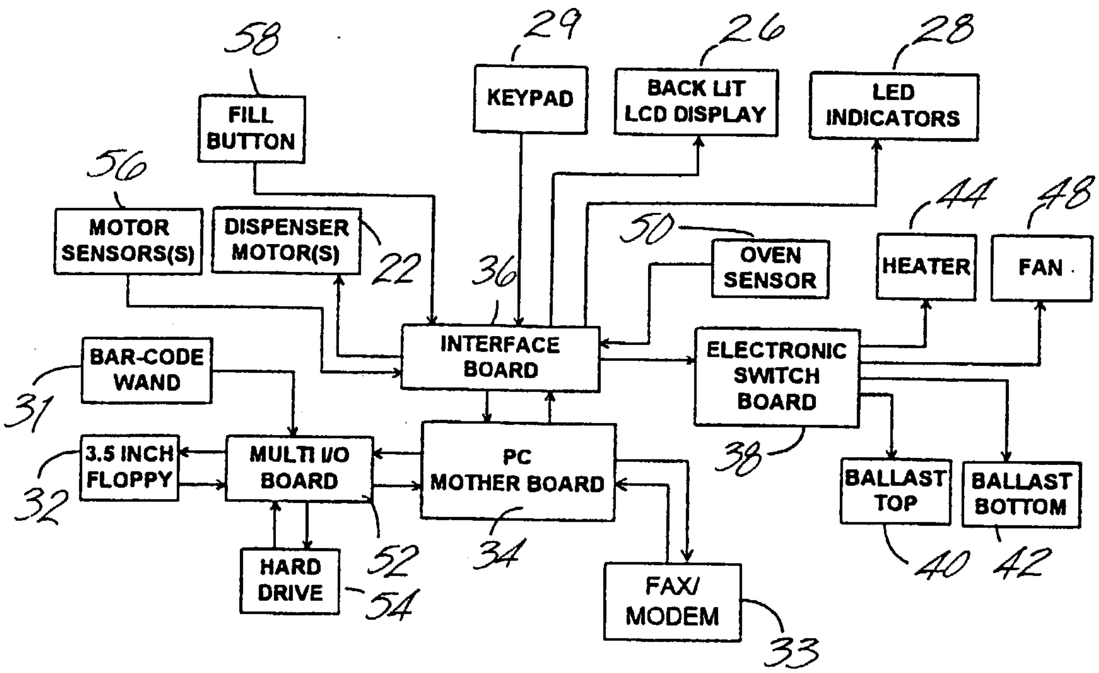


Fig. 2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KEYPAD
26
BACK LIT LCD DISPLAY
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LED INDICATORS
56
MOTOR SENSORS(S)
DISPENSER MOTOR(S)
22
36
50
OVEN SENSOR
44
HEATER
48
FAN
BAR-CODE WAND
31
INTERFACE BOARD
ELECTRONIC SWITCH BOARD
38
3.5 INCH FLOPPY
32
MULTI I/O BOARD
52
PC MOTHER BOARD
34
BALLAST TOP
40
BALLAST BOTTOM
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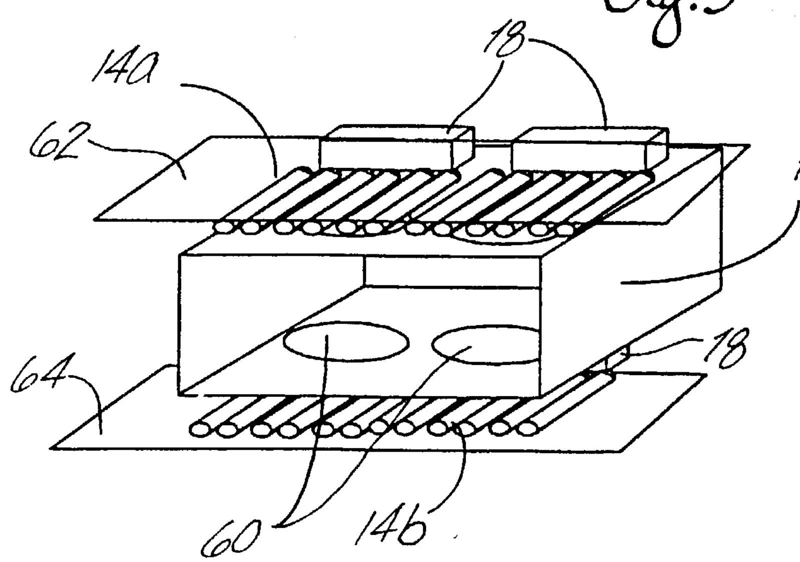
HARD DRIVE
54
FAX/ MODEM
33

Fig. 3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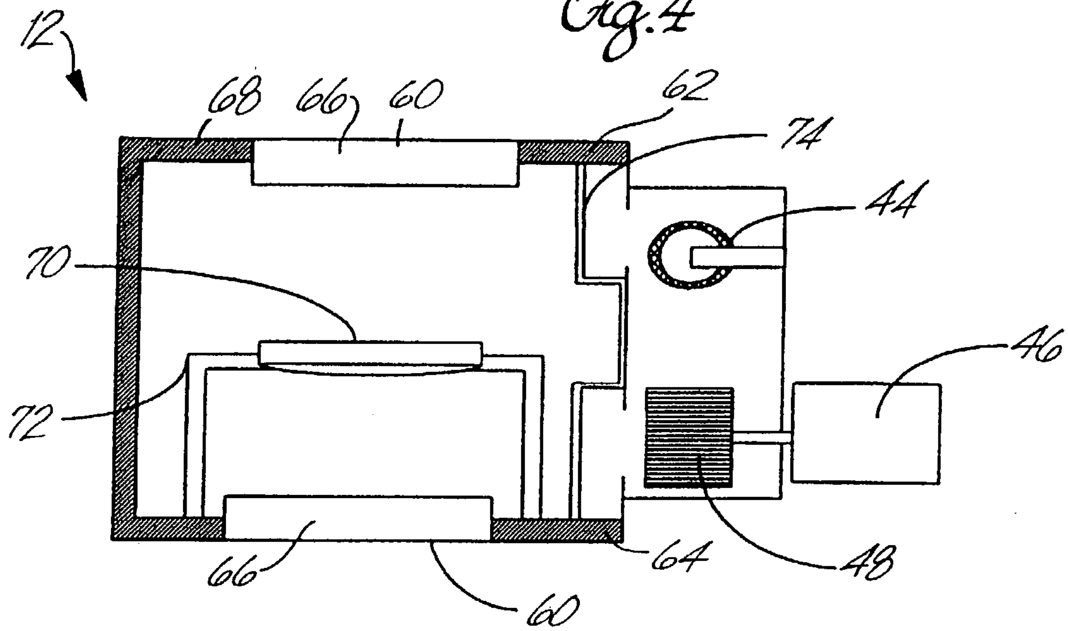
60
14b

Fig.4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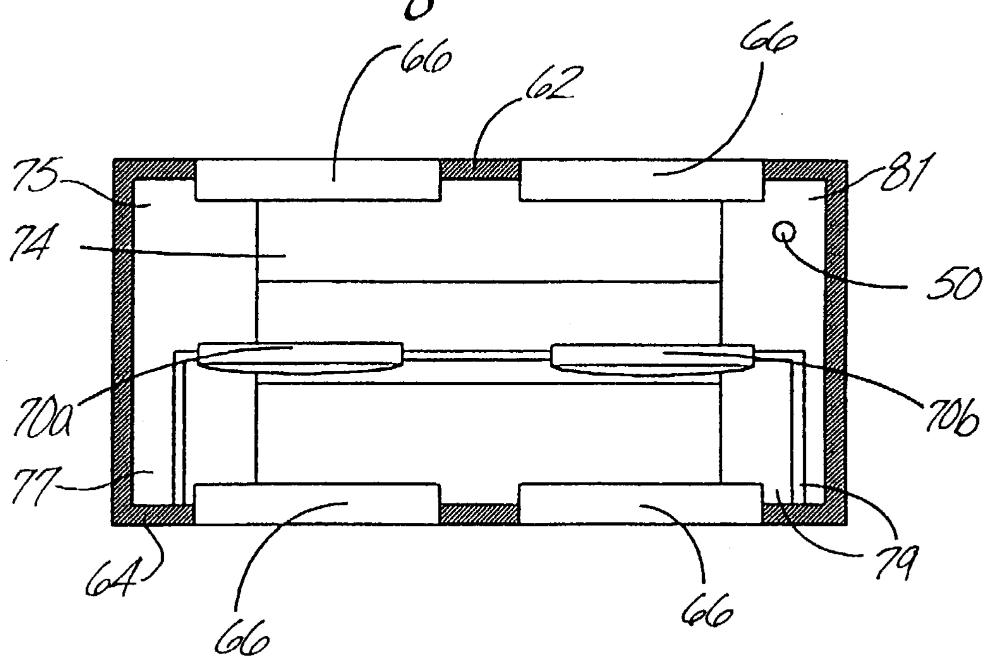
60

Fig.5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70b
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79
64
66
66

Fig. 6

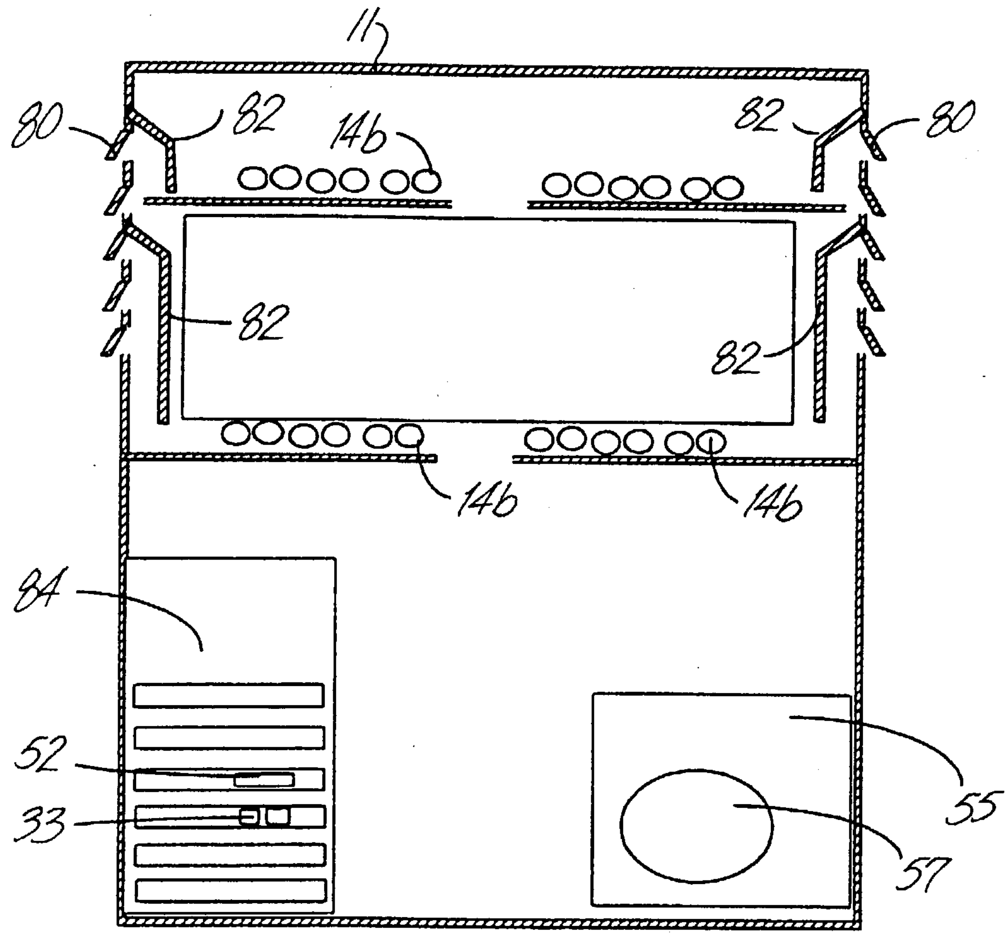
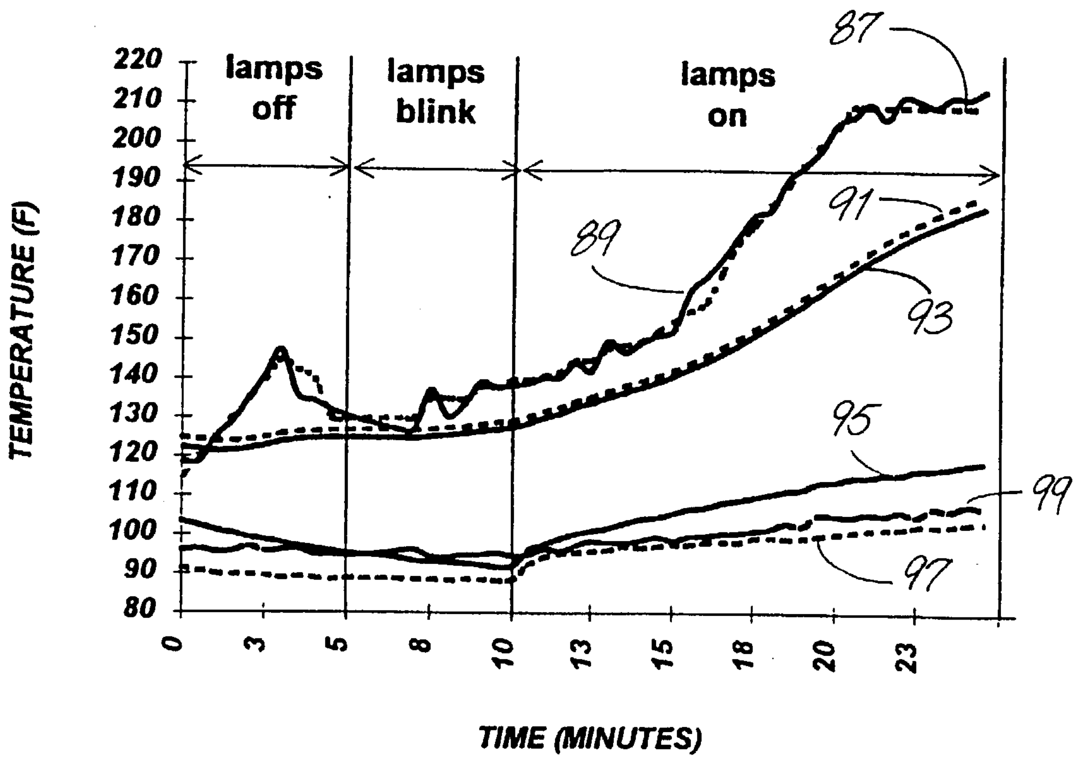


Fig. 7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lamps blink
lamps on
87
89
91
93
95
97
99
TEMPERATURE (F)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
0
3
5
8
10
13
15
18
20
23
TIME (MINUTES)

Fig. 8